PATENT APPLICATION
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APPLICATION

FOR

UNITED STATES LETTERS PATENT

TITLE: **METHOD AND SYSTEM FOR CONDENSATION OF UNPROCESSED WELL STREAM FROM OFFSHORE GAS OR GAS CONDENSATE FIELD**

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METHOD AND SYSTEM FOR CONDENSATION OF UNPROCESSED WELL STREAM FROM OFFSHORE GAS OR GAS CONDENSATE FIELD

Technical Field

The present invention relates to a method of condensing an unprocessed well stream from an offshore gas or gas condensate field for the purpose of producing a condensed well stream product that can be collected in a storage tank at sea for transport therefrom to land.

Background Art

The development of offshore gas or gas condensate fields of smaller size has often been considered as unprofitable because the costs of bringing the product therefrom onto the market would have been to high. Using technologies known thus far often requires complicated preprocessing and production plants for the preparation of products which are more suitable for the transport away from an exploitation field than an unprocessed well stream. In particular it has been common practice to separate liquids and solid particles, and any heavier hydrocarbons, from the well stream and then to process further constituents of the well stream individually, such as the extracted gas.

An example of the prior art is described in NO Patent No. 180 469 which relates to a method and system for offshore production of liquefied natural gas (LNG), wherein the well stream is supplied from a subsea production plant to a pipeline, in which it is cooled by the surrounding sea water. Then the well stream is supplied to a conversion plant provided on a ship, wherein liquids and solid particles are extracted and at least a part of the remaining gas is converted to liquid form for the transfer to storage tanks on board the ship.

Another example of the prior art is described in US Patent No. 6 378 330 which relates to a process for making pressurized liquefied natural gas (PLNG) from a gas stream rich in methane, wherein gas is condensed by first being cooled and then expanded. If the stream of natural gas contains heavier hydrocarbons which may freeze out during the liquefaction, they must, however, be removed prior thereto.

Furthermore, NO Patent No. 177 071 describes a method of dealing with petroleum gas from an oil or gas production field comprising ethane and heavier hydrocarbons, wherein liquids and solids are separated from a well stream and the gas of the well stream is

that part of the well stream is condensed, and condensed fractions of the prior to the expansion, unprocessed well stream are drawn off the expander and fed to the storage tank along with condensation products from the exit of the expander, thereby producing, without any preprocessing, a condensed well stream product made up of a mixture of liquids and solids which are collected in the storage tank for transport therefrom to land.

The invention also relates to a system for carrying out the method according to the invention, such as indicated in patent claim 8 appended hereto, and preferred embodiments of the invention are indicated in respective ones of the dependent claims.

In the method according to the invention there is no need for the well stream to undergo any form of preprocessing, not even separation. Hence, a processing plant for the implementation of the method may be correspondingly simplified. The method makes it possible to condense an unprocessed well stream into a product comprising a mixture of liquids and solids, *i.e.* a liquefied unprocessed well stream (LUWS), without any preprocessing of the feed, such as extraction of solid particles, *e.g.* sands, and removal of water, cleaning and drying.

In the context of the present invention, as it would be known in the present professional area, the expression "unprocessed well stream" is intended to mean the mixture that flows out of a well through a wellhead, or more wellheads joined in a manifold, under the normal production from a gas or gas condensate field without any preprocessing being undertaken, and of a composition, pressure and temperature that may vary from one field to another. An unprocessed well stream as just defined, may contain all possible components and phase mixtures that normally occur when producing from a gas or gas condensate field. Such a flow of fluids is the feed to the process of the invention.

Brief Description of Drawings

An example of how to carry out the method according to the invention is given below by reference to the accompanying drawings, wherein:

Figure 1 is a block diagram showing an embodiment of the invention, in which the final cooling is done by means of a heat exchanger and a cooling device included in the process chain,

Figure 2 is a block diagram showing an alternative embodiment of the invention, in which the final cooling is done by means of a cooling device in the form of a rechargeable, portable cooling energy accumulator,

product, *i.e.* a liquefied unprocessed well stream (LUWS) made up of a mixture of condensation products from each of the draining outlets 5A and the expander exit 5B.

Figure 2 is a block diagram showing an alternative embodiment of the invention, in which the process is the same as that in Figure 1 but where the final cooling prior to the arrival of the condensation products at the mixing vessel 6 is done by means of a cooling device which in this case is in the form of a cooling energy accumulator 9 adapted to be recharged ashore and transported to the gas or gas condensate field.

A process according to the method of the invention is now to be explained with reference to Figure 3 which gives an example of a pressure *vs.* enthalpy diagram showing the changes in the state of a well stream during the process. In the pressure *vs.* enthalpy diagram shown the point labelled ⑥ indicates the state of the well stream at the wellhead 1. The well stream emerging from a gas or gas condensate field is at a high temperature, *e.g.* of 90°C, and a high pressure, which in the diagram shown equals 200 bar. Through the cooling loop 3 the well stream is cooled to a temperature just above the hydrate temperature, corresponding to state ⑤ in Figure 3. Then the well stream is expanded isentropically, or near isentropically, to a state ③ in which the pressure is close to that of a storage tank 7.

During the expansion process ⑤ → ③ part of the well stream condenses and the condensed fraction is led to the storage tank 7 through draining outlets arranged on the expander 4 at the same time as energy is released which is convertible to electric power, as indicated by a generator 10 in Figures 1 and 2, approximately corresponding to the shift in enthalpy $h_5 - h_3$. To cause the well stream to become a mixture of liquids and solids the well stream is cooled from state ③ to state ⑦. For this cooling the energy released from the expansion ⑤ → ③ is used in addition to an external energy source 11 where required, *e.g.* from a ship. In this example, the pressure in the storage tank is chosen to be 15 bar but it may be set as low as 1 bar, if this is practical. In such an example the expansion would proceed from ⑤ → ② and subsequently the mixture would be cooled from ② → ① after the expansion process.

The difference between the process according to the invention and the conventional LNG processes is elucidated in Figure 4. According to the invention the condensation

cooling needed for the condensation of all the fluid, after the expansion, into liquids, for ending conditions corresponding to states ②, ③ og ④ in Figure 3, respectively.

Tabell 1

State (see Fig. 3)	Pressure (bar)	Temp. (°C)	Gas (% weight)	Liquid (% weight)	Free energy (kJ/kg)	Cooling need (kJ/kg)
②	1	-152,7	57,06	42,92	257	316
③	15	-93,4	64,52	35,48	147	287
④	40	-59,5	70,26	29,74	99	238

The *Gas* column indicates the gas percentage by weight after the drawing off of liquid in the expansion process.

The *Liquid* column indicates the liquid percentage by weight at the drawing off of liquid.

The *Free energy* column indicates the available free energy in the expansion process.

The *Cooling need* column indicates the cooling required to make the rest of the gas liquefied.

From the table it can be seen that the energy saved by using the method according to the invention amounts to 99 kJ/kg compared to a conventional process. A conventional process may utilize 33% and 61% of the available free energy when the pressure in the storage tank equals 15 bar and 1 bar, respectively. A process according to the present invention, however, is able to utilize all the free energy of the well stream.

8. A system for carrying out the method according to any one of the claims above, the system comprising:

- an expander (4) in which the expansion of the unprocessed well stream is effected isentropically, or near isentropically, to a state in which the pressure is close to that of a storage tank (7), the expander being provided with a plurality of draining outlets (5A),
- a heat exchanger (8) for the receipt of condensation products (5B) from the exit of the expander,
- a mixing vessel (6) for the receipt of condensed fractions of the well stream taken from the expander through its draining outlets and for the receipt of condensation products which have passed through the heat exchanger,
- a storage tank (7) for storing a mixture of liquids and solids (LUWS) received from the mixing tank, for transport therefrom to land.

9. A system according to claim 8, further comprising a cooling device (9) associated with the heat exchanger (8), and where energy generated in the expander (4) by direct condensation therein of part of the well stream, is utilized in the cooling device (9).

10. A system according to claim 9, wherein the cooling device (9) takes the form of a cooling energy accumulator adapted to be recharged ashore and transported to the offshore production field.

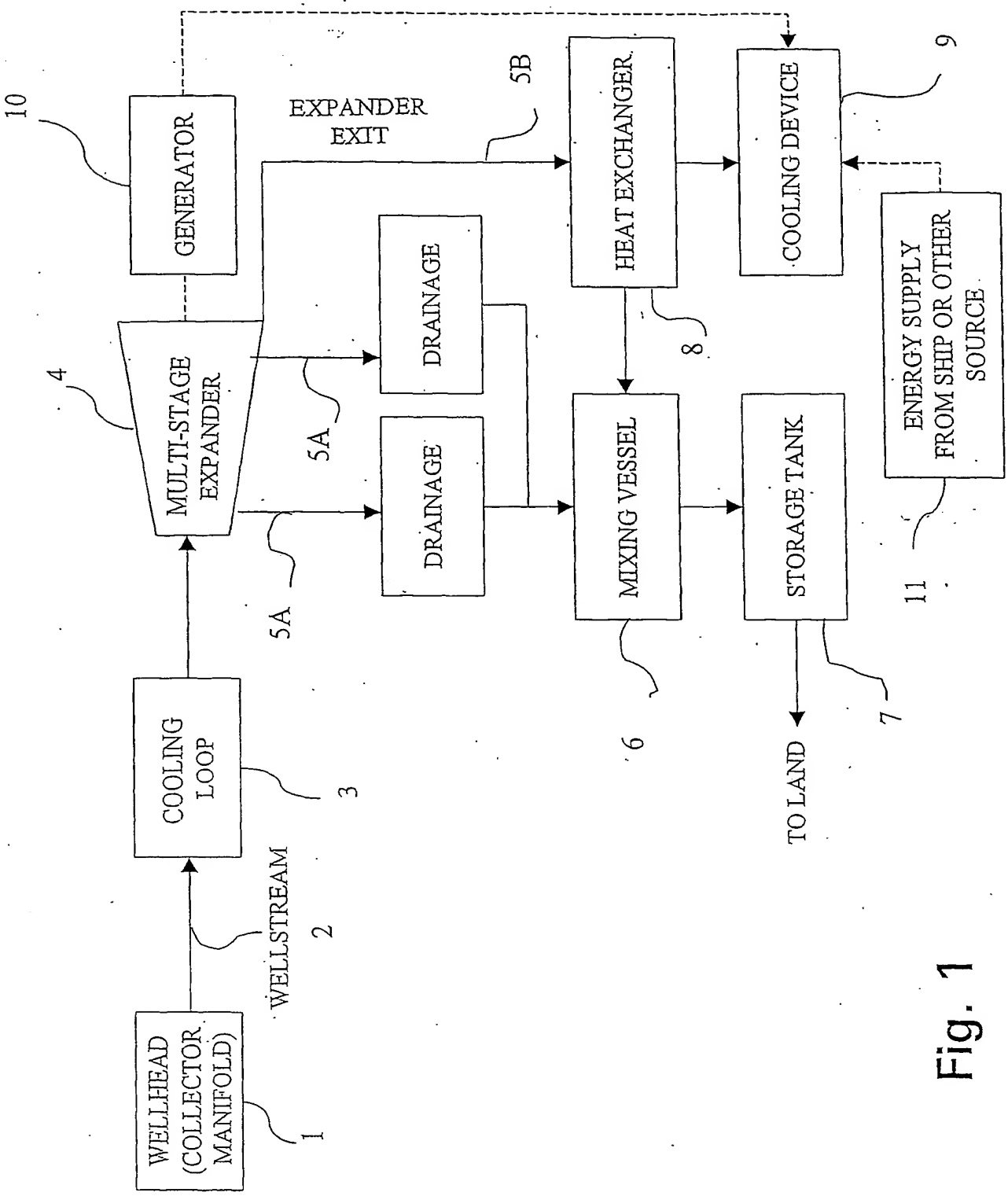
WELLHEAD (COLLECTOR MANIFOLD)
1
WELLSTREAM
2
COOLING LOOP
3
MULTI-STAGE EXPANDER
4
5A
5A
EXPANDER EXIT
5B
DRAINAGE
DRAINAGE
HEAT EXCHANGER
8
COOLING DEVICE
9
GENERATOR
10
ENERGY SUPPLY FROM SHIP OR OTHER SOURCE
11
MIXING VESSEL
6
STORAGE TANK
7
TO LAND

Fig. 1

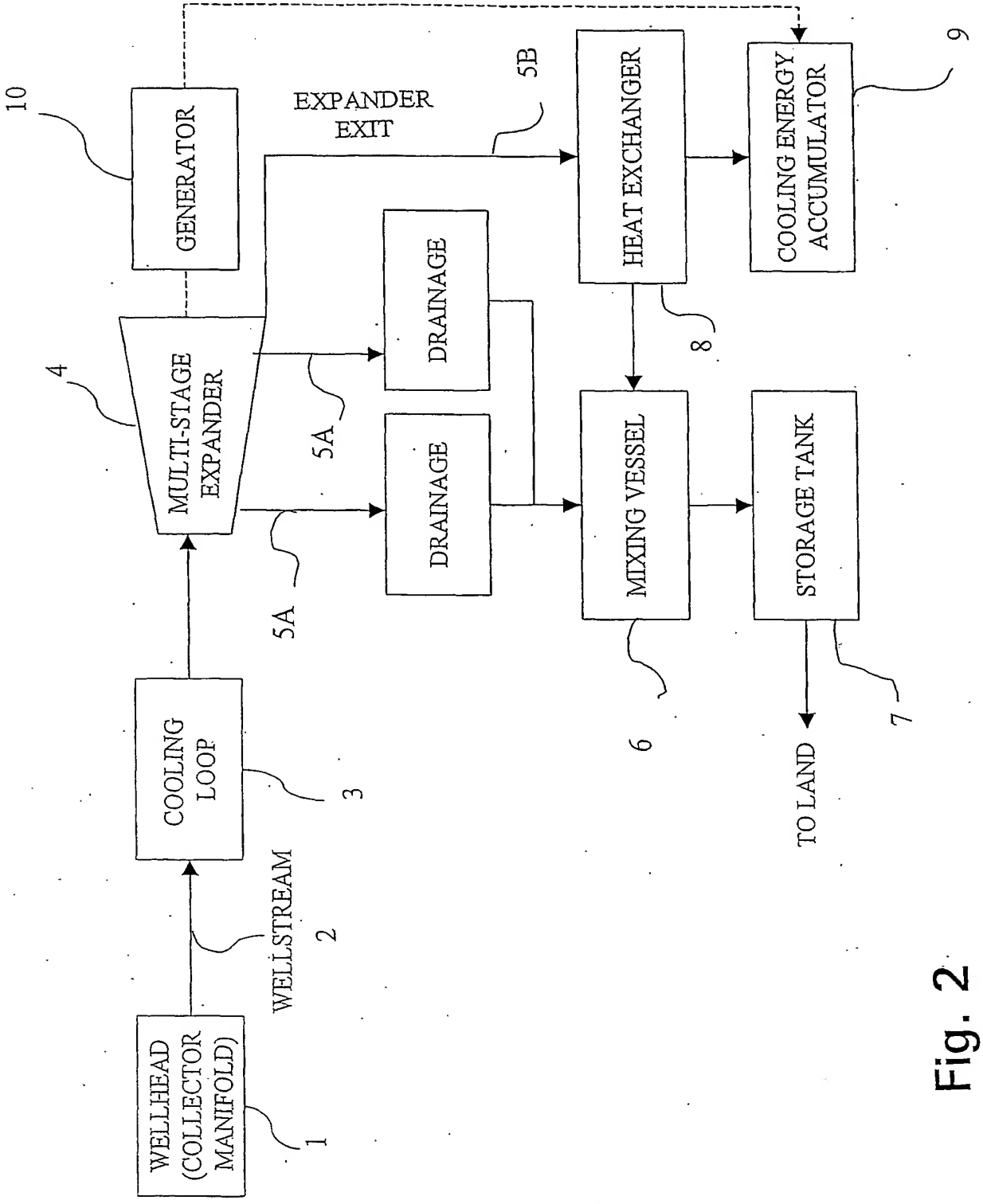

Fig. 2

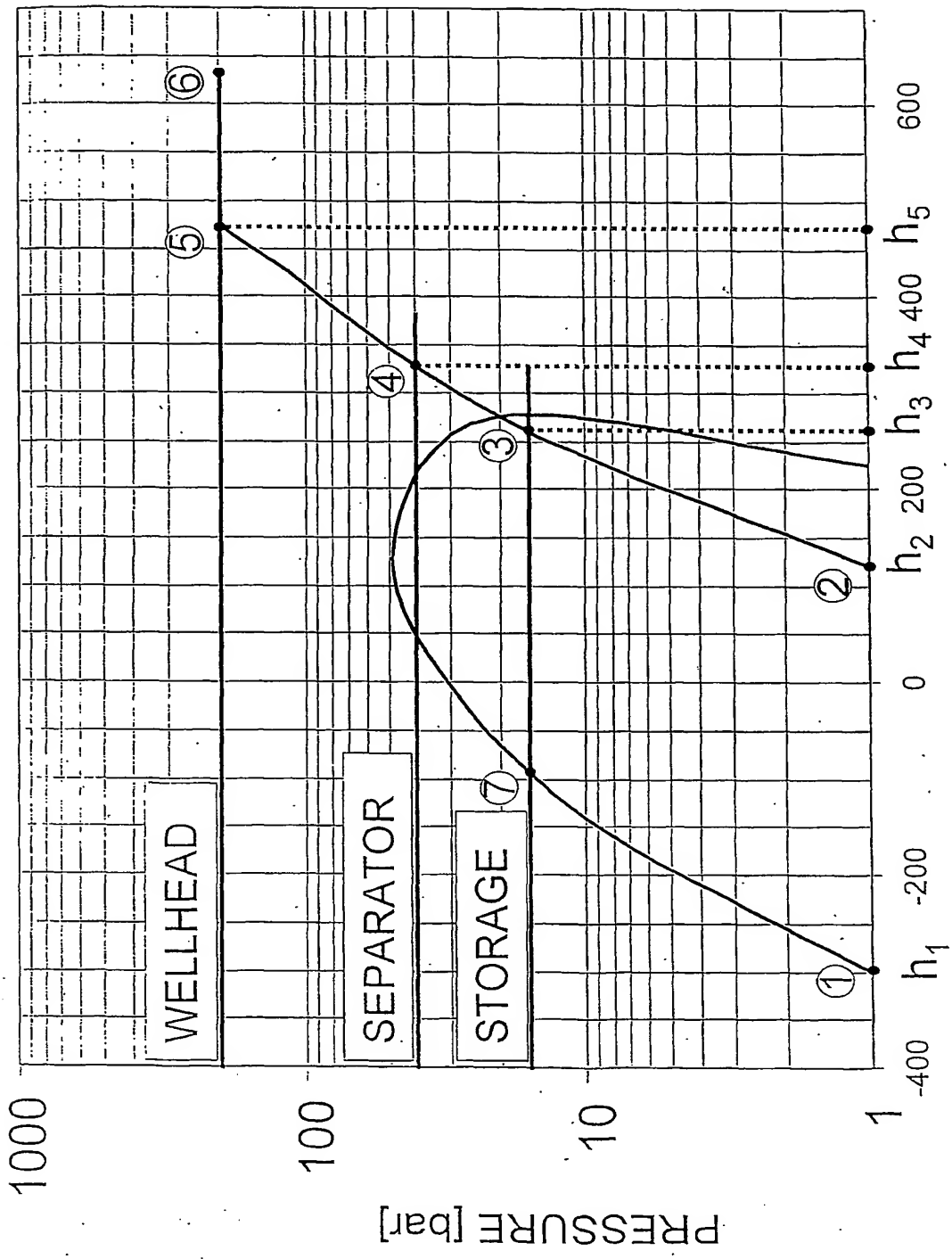
WELLHEAD
SEPARATOR
STORAGE
1000
100
10
1
PRESSURE [bar]
-400
-200
0
200
400
600
ENTHALPY [kJ/kg]
h1
h2
h3
h4
h5
1
2
3
4
5
6
7

Fig. 3

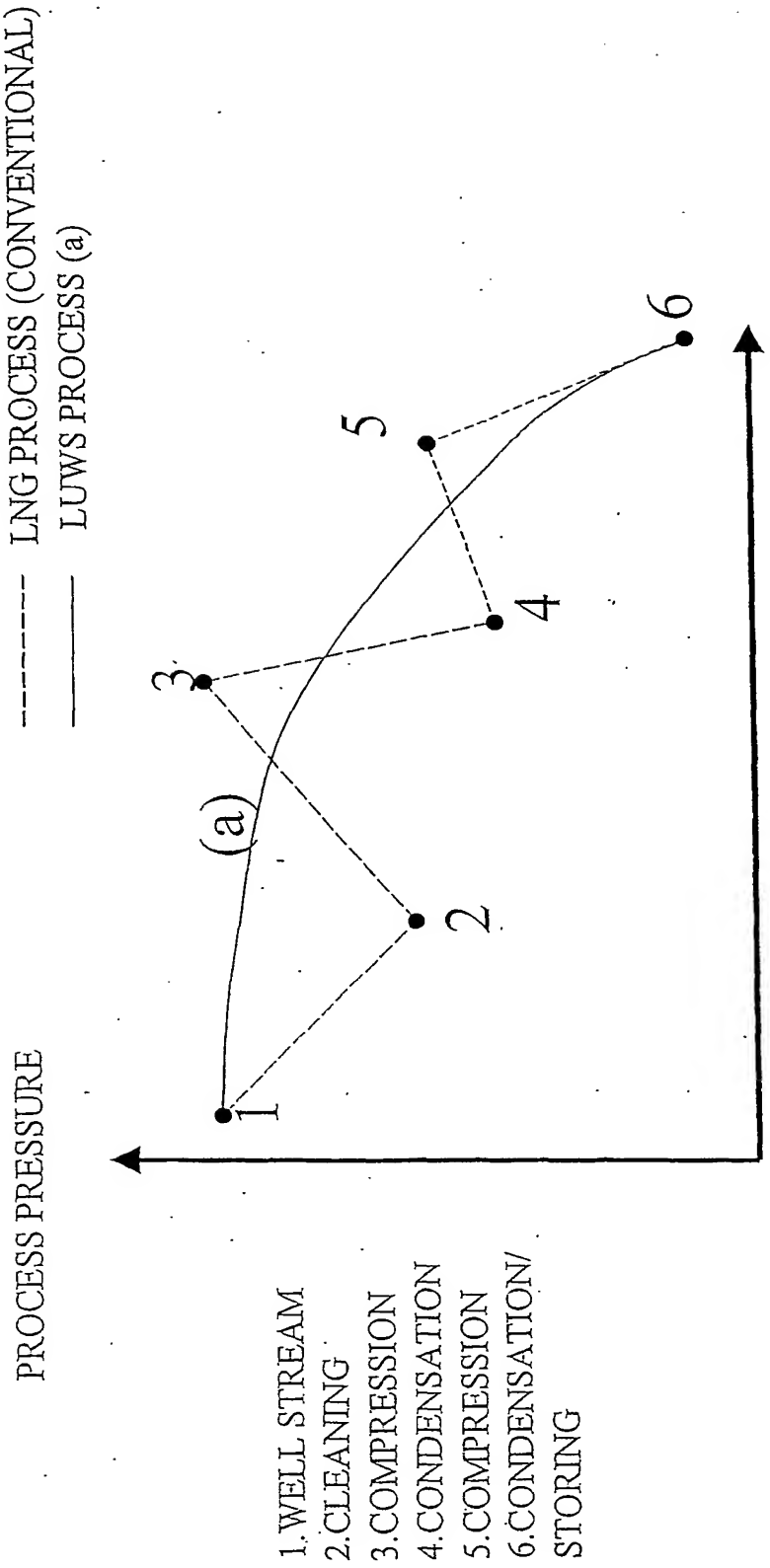

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 2003/000441

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F25J 1/02, F25J 3/06, B63B 22/02
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F25J, B63B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 6085528 A (R.M. WOODALL ET AL), 11 July 2000 (11.07.2000), column 8, line 53 - column 10, line 22, figures 1,2	1-10
A	WO 9617766 A1 (DEN NORSKE STATS OLJESELSKAP A.S.), 13 June 1996 (13.06.1996), whole document	1-10
A	US 6378330 B1 (M. MINTA ET AL), 30 April 2002 (30.04.2002), whole document	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"P" document published prior to the international filing date but later than the priority date claimed
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"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 March 2004	10 -03- 2004
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Inger Löfving / MRo Telephone No. +46 8 782 25 00

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Information on patent family members

27/02/2004

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